a first sinusoid at the frequency of the original sinusoidal modulation of the bias current, and a second sinusoid at double that original frequency. The two separate multiplied outputs are then each low pass filtered and the phase calculated. Thereafter the displacement is determined using at least the phase.

[0163] The DC voltage generator **1002** is used to generate a constant bias voltage. A sine wave generator **1004** may produce an approximately single frequency sinusoid signal, to be combined with constant voltage. As shown in FIG. **10**, the sine wave generator **1004** is a digital generator, though in other implementations it may produce an analog sine wave. The low pass filter **1006**A provides filtering of the output of the DC voltage generator **1002** to reduce undesired varying of the constant bias voltage. The bandpass filter **1006**B can be used to reduce distortion and noise in the output of the sine wave generator **1004** to reduce noise, quantization or other distortions, or frequency components of its signal away from its intended modulation frequency, ω_m.

[0164] The circuit adder **1008** combines the low pass filtered constant bias voltage and the bandpass filtered sine wave to produce on link **1009** a combined voltage signal which, in the embodiment of FIG. **10**, has the form $V_0+V_m \sin(\omega_m t)$. This voltage signal is used as an input to the voltage-to-current converter **1010** to produce a current to drive the lasing action of the VCSEL diode **1014**. The current from the voltage-to-current converter **1010** on the line **1013** can have the form $I_0+I_m \sin(\omega_m t)$.

[0165] The VCSEL diode **1014** is thus driven to emit a laser light modulated as described above. Reflections of the modulated laser light may then be received back within the lasing cavity of VCSEL diode **1014** and cause self-mixing interference. The resulting self-mixing interference light may be detected by photodetector **1016**. As described above, in such cases the photocurrent output of the photodetector **1016** on the link **1015** can have the form: $I_{PD}=i_0+i_m \sin(\omega_m t)+\gamma \cos(\varphi_0+\varphi_m \sin(\omega_m t))$. As the I/Q components to be used in subsequent stages are based on just the third term, the first two terms can be removed or reduced by the differential transimpedance amplifier and anti-aliasing (DTIA/AA) filter **1018**. To do such a removal/reduction, a proportional or scaled value of the first two terms is produced by the voltage divider **1012**. The voltage divider **1012** can use as input the combined voltage signal on the link **1009** produced by the circuit adder **1008**. The output of the voltage divider **1012** on link **1011** can then have the form $\alpha(V_0+V_m \sin(\omega_m t))$. The photodetector current and this output of the voltage divider **1012** can be the inputs to the DTIA/AA filter **1018**. The output of the DTIA/AA filter **1018** can then be, at least mostly, proportional to the third term of the photodetector current.

[0166] The output of the DTIA/AA filter **2018** may then be quantized for subsequent calculation by the analog-to-digital converter (ADC) block **1020**. Further, the output of the ADC block **1020** may have residual signal component proportional to the sine wave originally generated by the sine wave generator **1004**. To filter this residual signal component, the originally generated sine wave can be scaled (such as by the indicated factor of β) at multiplier block **1024**C, and then subtracted from the output of ADC block **1020**. The filtered output on link **1021** may have the form $A+B \sin(\omega_m t)+C \cos(2\omega_m t)+D \sin(3\omega_m t)+\ldots$, from the Fourier expansion discussed above. The filtered output can then be used for extraction of the I/Q components by mixing.

[0167] The digital sine wave originally generated by sine wave generator **1004** onto link **1007** is mixed (multiplied) by the multiplier block **1024***a* with the filtered output on link **1007**. This product is then low pass filtered at block **1028***a* to obtain the Q component discussed above.

[0168] Also, the originally generated digital sine wave is used as input into the squaring/filtering block **1026** to produce a digital cosine wave at a frequency double that of the originally produced digital sine wave. The digital cosine wave is then mixed (multiplied) at the multiplier component **1024***b* with the filtered output of the ADC block **1020** on link **1021**. This product is then low pass filtered at component **1028***b* to obtain the I component discussed above.

[0169] The Q and the I components are then used by the phase calculation component **1030** to obtain the phase from which the displacement of the target can be calculated, as discussed above.

[0170] One skilled in the art will appreciate that while the embodiment shown in FIG. **10** makes use of the digital form of the originally generated sine wave produced by sine wave generator **1004** onto link **1007**, in other embodiments the originally generated sine wave may be an analog signal and mixed with an analog output of the DTIA/AA **1018**.

[0171] The circuit of FIG. **10** can be adapted to implement the modified I/Q method described above that uses $Q' \propto \text{Lowpass}\{I_{PD} \times \sin(3\omega_m t)\}$. Some such circuit adaptations can include directly generating both mixing signals $\sin(2\omega_m t)$ and $\sin(3\omega_m t)$, and multiplying each with the output of the output of the ADC block **1020**, and then applying respective low pass filtering, such as by the blocks **1028***a,b*. The differential TIA and anti-aliasing filter may then be replaced by a filter to remove or greatly reduce the entire component of I_{PD} at the original modulation frequency ω_m. One skilled in the art will recognize other circuit adaptations for implementing this modified I/Q method.

[0172] In additional and/or alternative embodiments, the I/Q time domain based methods just described may be used with the spectrum based methods of the first family of embodiments. The spectrum methods of the first family can be used at certain times to determine the absolute distance to the target, and provide a value of L_0. Thereafter, during subsequent time intervals, any of the various I/Q methods just described may be used to determine ΔL.

[0173] In additional and/or alternative embodiments, the spectrum methods based on triangle wave modulation of a bias current of a VCSEL may be used as a guide for the I/Q time domain methods. The I/Q methods operate optimally in the case that $J_1(b)=J_2(b)$, so that the I and Q components have the same amplitude. However, b depends on the distance L. An embodiment may apply a triangle wave modulation to the VCSEL's bias current to determine a distance to a point of interest. Then this distance is used find the optimal peak-to-peak sinusoidal modulation of the bias current to use in an I/Q approach. Such a dual method approach may provide improved signal-to-noise ratio and displacement accuracy obtained from the I/Q method.

[0174] Referring now to FIG. **11**, there is shown an exemplary structural block diagram of components of an electronic device **1100**, such as the embodiments described above. The block diagram is exemplary only; various embodiments described above may be implemented using other structural components and configurations. The elec-